Journal Review

Automatica

(Survey Paper) Robust control of uncertain systems: Classical results and recent developments

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Abstract

This paper presents a survey of the most significant results on robust control theory. In particular, we study the modeling of uncertain systems, robust stability analysis for systems with unstructured uncertainty, robustness analysis for systems with structured uncertainty, and robust control system design including H_∞ control methods. The paper also presents some more recent results on deterministic and probabilistic methods for systems with uncertainty.

Distributed finite-time consensus of nonlinear systems under switching topologies

Vol. 50, No.6, Page 1626-1631

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Abstract

In this paper, the finite time consensus problem of distributed nonlinear systems is studied under the general setting of directed and switching topologies. Specifically, a contraction mapping argument is used to investigate performance of networked control systems, two classes of varying topologies are considered, and distributive control designs are presented to guarantee finite time consensus. The proposed control scheme employs a distributed observer to estimate the first left eigenvector of graph Laplacian and, by exploiting this knowledge of network connectivity, it can handle switching topologies. The proposed methodology ensures finite time convergence to consensus under varying topologies of either having a globally reachable node or being jointly strongly connected, and the topological requirements are less restrictive than those in the existing results. Numerical examples are provided to illustrate the effectiveness of the proposed scheme.

Optimal control for multi-agent persistent monitoring

Vol. 50, No.6, Page 1663-1668

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Abstract

The problem of persistent monitoring using a network of mobile agents is considered in this paper, where the goal is to drive the uncertainty of all targets to zero and patrol the whole mission domain. The uncertainty at each target point is assumed to evolve nonlinearly in time. Given a closed path, it is proved that multi-agent persistent monitoring with the minimum patrol period can be achieved by optimizing the agents' moving speed and initial locations on the path. It is also shown that the proposed approach provides a less conservative condition for persistent tasks with a constraint on the patrol period with respect to the existing works. Simulation results illustrate the effectiveness of the proposed persistent monitoring algorithm.

On stability and regulation performance for flexible-joint robots with input/output communication delays

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Abstract

Networked control of robotic systems is widely recognized as a potentially transformative technological enabler for several applications. However, the issues of time delays in communication and recovery from data losses have emerged as the pivotal issues that have stymied practical deployment. The study for control of robotic system with input/output communication delays has attracted many researchers' attention, but the existing results have been primarily developed for rigid-joint robots. Since joint flexibility is largely unavoidable in practical manipulators, in this paper the set-point control problem for flexible-joint robots with input/output communication delays is studied. It is demonstrated that the scattering variables address the stability problem for unknown constant delays, however, in contrast to the rigid-robot case, they cannot guarantee set-point regulation. In addition, we compute the explicit dependence of the regulation errors on the communication delays, control gains, and the desired set-point configuration. Without exact knowledge of time delays, a scattering variable based controller with position feedback is subsequently studied in this paper to guarantee stability with improved regulation performance. The control architecture is further extended to the case with time-varying delays. Simulation results are presented to validate the efficacy of the proposed control algorithms.

Adaptive control of MIMO time-varying systems with indicator function based parametrization

Vol. 50, No.5, Page 1369-1380

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Abstract

This paper studies a new solution framework for adaptive control of a class of MIMO time-varying systems with indicator function based parametrization, motivated by a general discrete-time MIMO Takagi–Sugeno (T–S) fuzzy system model in an input–output form with unknown parameters. An indicator (membership) function based parametrization has some favorable capacity to deal with certain large parameter variations. A new discrete-time MIMO system prediction model is derived for approximating a nonlinear dynamic system, and its system properties are clarified. An adaptive control scheme is developed, with desired controller parametrization and stable parameter estimation for control of such uncertain MIMO time-varying systems. A control singularity problem is addressed and the closed-loop stability and output tracking properties are analyzed. This work provides a new method for multivariable T–S fuzzy system modeling and adaptive control. An illustrative example and simulation results are presented to demonstrate the proposed novel concepts and to verify the desired adaptive control system performance.

Output feedback tracking control of stochastic Lagrangian systems and its application

Vol. 50, No.5, Page 1424-1433

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Abstract

This paper focuses on the problem of output feedback tracking control for stochastic Lagrangian systems with the unmeasurable velocity. Under some milder assumptions, using the structural properties of Lagrangian systems, a reduced-order observer is skillfully constructed to estimate the velocity. Based on the observer, an output feedback tracking controller is designed such that the mean square of the tracking error converges to an arbitrarily small neighborhood of zero by tuning design parameters. The efficiency of the controller is demonstrated by a stochastic mechanical model.

Sensor management for multi-target tracking via multi-Bernoulli filtering

Vol. 50, No.4, Page 1135-1142

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Abstract

In multi-object stochastic systems, the issue of sensor management is a theoretically and computationally challenging problem. In this paper, we present a novel random finite set (RFS) approach to the multi-target sensor management problem within the partially observed Markov decision process (POMDP) framework. The multi-target state is modelled as a multi-Bernoulli RFS, and the multi-Bernoulli filter is used in conjunction with two different control objectives: maximizing the expected Rényi divergence between the predicted and updated densities, and minimizing the expected posterior cardinality variance. Numerical studies are presented in two scenarios where a mobile sensor tracks five moving targets with different levels of observability.

Reinforcement Q-learning for optimal tracking control of linear discrete-time systems with unknown dynamics

Vol. 50, No.4, Page 1167-1175

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Abstract

In this paper, a novel approach based on the Q-learning algorithm is proposed to solve the infinite-horizon linear quadratic tracker (LQT) for unknown discrete-time systems in a causal manner. It is assumed that the reference trajectory is generated by a linear command generator system. An augmented system composed of the original system and the command generator is constructed and it is shown that the value function for the LQT is quadratic in terms of the state of the augmented system. Using the quadratic structure of the value function, a Bellman equation and an augmented algebraic Riccati equation (ARE) for solving the LQT are derived. In contrast to the standard solution of the LQT, which requires the solution of an ARE and a noncausal difference equation simultaneously, in the proposed method the optimal control input is obtained by only solving an augmented ARE. A Q-learning algorithm is developed to solve online the augmented ARE without any knowledge about the system dynamics or the command generator. Convergence to the optimal solution is shown. A simulation example is used to verify the effectiveness of the proposed control scheme.

Stochastic stability of Positive Markov Jump Linear Systems

Vol. 50, No.4, Page 1181-1187

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Abstract
This paper investigates on the stability properties of Positive Markov Jump Linear Systems (PMJLS's), i.e. Markov Jump Linear Systems with nonnegative state variables. Specific features of these systems are highlighted. In particular, a new notion of stability (Exponential Mean stability) is introduced and is shown to be equivalent to the standard notion of 1-moment stability. Moreover, various sufficient conditions for Exponential Almost-Sure stability are worked out, with different levels of conservatism. The implications among the different stability notions are discussed. It is remarkable that, thanks to the positivity assumption, some conditions can be checked by solving Linear Programming feasibility problems.

IEEE T-Ro

Control of a Group of Mobile Robots Based on Formation Abstraction and Decentralized Locational Optimization

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Abstract
In this paper, we propose a new method of controlling a group of mobile robots based on formation abstraction. The shape of a formation is represented by a deformable polygon, which is constructed by bending a rectangle, to go through narrow spaces without colliding with obstacles. If the trajectory of the front end point, as well as the width and the length of the formation, are given, the formation automatically reshapes itself to fit the area through which the front part of the group has already safely passed. Furthermore, the robots continuously try to optimize their positions to decrease the risk of collisions by integrating a decentralized locational optimization algorithm into the formation control. We show that the objective function, taking into account the distance between robots, does not decrease for fixed and nonconvex polygonal formation shapes if the zero-order hold control is applied for a sufficiently short sampling period. We also analyze the influence of the decentralized locational optimization algorithm on the objective function in the case of variable formations. The effectiveness of the proposed method is demonstrated in both simulations and real robot experiments.

Robotic Probing of Nanostructures inside Scanning Electron Microscopy

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Abstract
Probing nanometer-sized structures to evaluate the performance of integrated circuits (IC) for design verification and manufacturing quality monitoring demands precision nanomanipulation technologies. To minimize electron-induced damage and improve measurement accuracy, scanning electron microscopy (SEM) imaging

parameters must be cautiously chosen to ensure low electron energy and dosage. This results in significant image noise and drift. This paper presents automated nanoprobing with a nanomanipulation system inside a standard SEM. We achieved SEM image denoising and drift compensation in real time. This capability is necessary for achieving robust visual tracking and servo control of nanomanipulators for probing nanostructures in automated operation. This capability also proves highly useful to conventional manual operation by rendering real-time SEM images that have little noise and drift. The automated system probed nanostructures on an SEM metrology chip as surrogates of electronic features on IC chips. Success rates in visual tracking and Z-contact detection under various imaging conditions were quantitatively discussed. The experimental results demonstrate the system’s capability for automated probing of nanostructures under IC-chip-probing relevant electron microscope imaging conditions.